Jupiter at 4.8 μm

MIRLIN User Guide

Jupiter at 10.3 μm

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Jupiter at 24.5 μm

Contents

1 Introduction

This document is a short description of how to use MIRLIN. It is hoped that there is enough information here that anyone can obtain good, trustworthy data with MIRLIN without excessive interaction from the development team. You will, of course, have to be the judge of that. Comments are welcome and can be e-mailed to *Michael.E.Ressler@jpl.nasa.gov*.

What is MIRLIN? MIRLIN (Mid-InfraRed Large-well Imager, "No, the 'n' doesn't stand for anything") is a mid-infrared (5–26 μm) camera built by Michael Ressler and Michael Werner at JPL. The camera is based on Boeing's HF–16 128×128 Si:As BIB array. This array was unusual in that it has a well depth of approximately 30 million electrons; this allows the use traditional broadband astronomical filters (such as N and Q) without sacrificing a reasonable field-of-view or using ultrafast (thus expensive) support electronics. Measured platescales are roughly 0.15 arcsec/pixel (19 arcsec FOV) at the Palomar 5–m, 0.475 arcsec/pixel (61 arcsec FOV) at the NASA IRTF 3–m, and 0.138 arcsec/pixel at the Keck II (17.7 arcsec FOV).

The camera provides wavelength coverage from 5–26 μm by having a thirteen fixed filters and a 2%, 7–14 μm circular variable filter (CVF) mounted in two filter wheels. The fixed filters can be chosen from among the N, Q-short, and Q-long filters, the 6-filter 10 μm silicate set, and a 7-filter narrow-band 20 μm set.

2 The User Interface

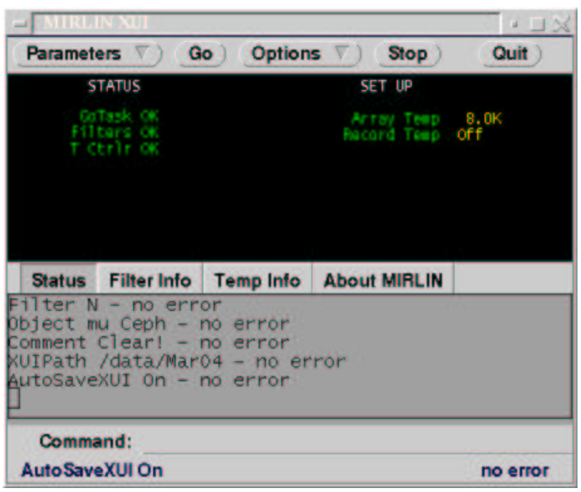


Figure 1: The XUI Main Window

The user interface to MIRLIN is controlled by two programs, MXUI and MVF (which are very similar to the XUI and VF programs used by the IRTF facility instruments NSFCAM and CSHELL). MXUI stands for MIRLIN X User Interface and is where all the parameters to control MIRLIN are entered. Figure 1 shows the default startup panel. MVF stands for MIRLIN View FITS, and is really a general purpose FITS file viewer which happens to have some MIRLIN-specific knowledge built into it. It is discussed more later.

To set up to take your first image, you should setup/-check the following items (everything is in XUI). Under the **Parameters** menu, select **Change**. This should pop up a new window labeled `Observing Parameters` (Figure 2). Make sure the camera mode is **Basic**, not **Sim** (the simulation mode will generate nice fuzzy pictures of the Galactic Center, which is probably not what you want). Set the integration time (**Itime**, this is in *milliseconds*!) so that the mean background (indicated by **Sky Value**) is 6000–8000 counts per frame, and choose the number of coadds so that the chop frequency will be a few Hz. Choose the observing mode—this will usually be **Chop/Nod**, but either **Nod** or **Chop** alone may be useful depending on sky conditions. The **Chops** parameter is the number of +/- beam pairs performed; **Cycles** is the number of A/B telescope nod pairs performed. Total on-source integration time assuming Chop/Nod mode is **Itime**×**Coadds**×**Chops**×**Cycles**. There will be an equal amount of time spent off-source. (The actual observation will take longer than the sum of these two times due to readout overhead and settling times.)

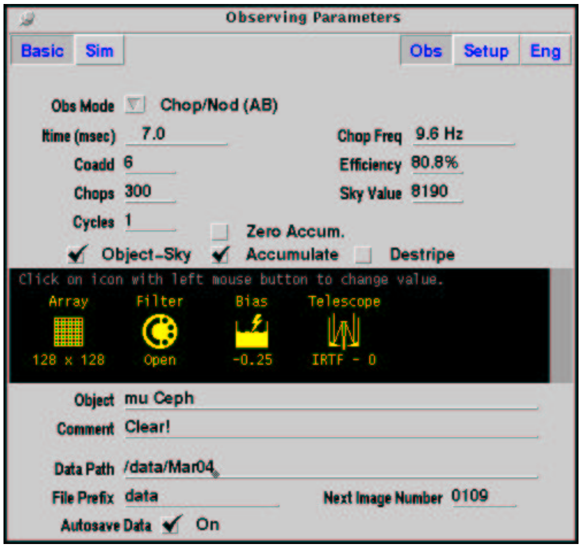


Figure 2: The "Obs" Window

To see a difference frame (Object - Sky) at the end of a chop sequence, make certain the **Object-Sky** box is checked. To see the sum of difference frames when many cycles are performed, make certain the **Accumulate** box is checked. To clear this accumulator frame, click on **Zero Accum**. Note that you *must* clear the accumulator manually. If you change filters or move the telescope, the accumulator will happily add the new data to the old, creating quite a mess in the process. We had played around with automatic clearing, but there are times when one deliberately wants to do something messy, so we decided to leave it be.

If you are seeing a vertical stripe pattern in your data, this is due to a low level read noise property of the array—you can select the **Destripe** option to have the *display* destriped automatically. The data written to disk are not modified by this option! You will have to destripe the data again during the data reduction process. Also, beware of this option with extended objects. It works quite well with point sources, but it assumes that the median value of any pair of columns is zero, so you can get very funky artifacts if the object has bright extensions.

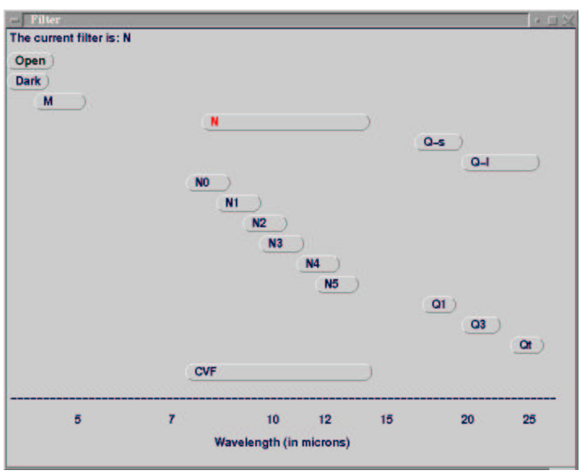


Figure 3: The Filter Chart

Click on the Filter icon to select a filter. A selection chart should appear which shows the available filters (Figure 3), plotted roughly by central wavelength, and the button width indicative of the passband. Click on the filter button you desire. A flag on the main MXUI window will indicate that the filters are in motion; in any case, it should never take longer than about 10 seconds to swap filters, even in the worst case combination.

If you want to set the CVF, click the **CVF** button on the filter chart, then type in the wavelength in the small pop-up box (Figure 4, left). The allowed wavelength range is approximately 7.5–13.7 μm.

Click on the Bias icon to get the popup to set the detector bias voltage (Figure 4, right). Legal values are 0–2 V with 0.75 V being the choice for the current detector array. Higher bias voltages are more sensitive than lower ones, but excess noise appears when the bias is raised above 0.75 V. *Don't change this unless you really know what you are doing and have an excrutiatingly good reason for doing so.*

(a) The CVF wavelength popup. (b) The bias voltage popup.

Figure 4: Random little dialog boxes

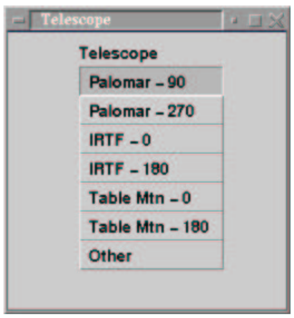


Figure 5: The telescope selection popup.

Click on the Telescope icon to set the telescope location and orientation (Figure 5). At this time, it affects only the telescope name and the orientation of the first pixel printed in the FITS file header and the orientation of the difference images displayed in VF. This will attempt to always have north up and east to the left in the image display. We hope to eventually have it also select the default nod dead-time, the telescope communication mode, etc.

Check the various text fields below the icons to ensure reasonable values. **Object** and **Comment** should be obvious; **Data Path** selects the directory in which to store the data (please make a subdirectory off of /data, *e.g.* /data/Nov07, at Palomar or Keck, and off /scrs1 at the IRTF; use of the date in the directory name is strongly encouraged), **File Prefix** chooses the text prefix attached to every data file (common practice is to just leave it “data” or to change it for each object observed; *e.g.* “aboo”, “jup”, “NGC1514”, etc.), and **Next Image Number** sets the file suffix (for your own sanity, do not reset this for each object; use a running sequence for the entire night). **Autosave Data** indicates whether to automatically save the data as it is taken (you must use the **Save File** command in VF to save it if you don’t automatically save it here, and trust me, that is painful).

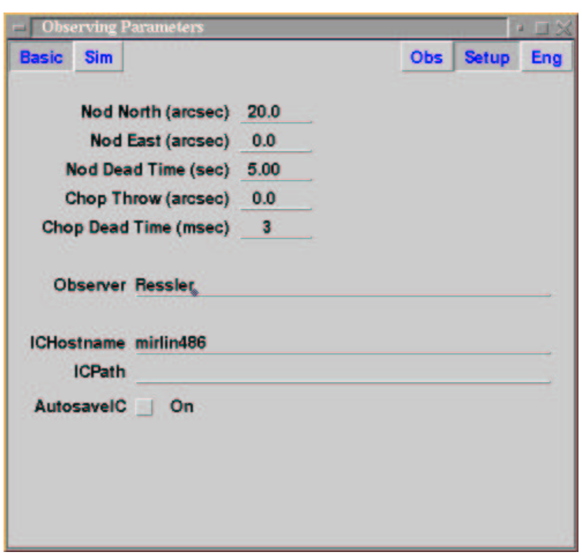


Figure 6: The “Setup” Window

Now select the **Setup** window (from the Obs/-Setup/Eng bar in the upper right, Figure 6). The **Nod East** and **Nod North** selections set the nod distances for Palomar and Keck only (the telescope operator sets them at the IRTF, though it is good practice to type in what you told the operator so that it gets recorded in the FITS header). Use negative values for west or south moves. The **Nod Dead Time** is the amount of time the program waits after a telescope nod before taking data. At Palomar, this value will be about 10 seconds depending on the nod distance; at the IRTF, this time should be 2–3 seconds; at Keck, 15 seconds. **Chop Throw** programs the chopper throw in arcseconds at Palomar; again enter a value at the IRTF and Keck for posterity. **Chop Dead Time** sets the delay time between the chop signal transition and the start of the integration. This should be about 2 msec at Palomar, 3–7 msec at the IRTF, and 10–30 msec at Keck—it varies drastically with the throw distance because of the active control Keck uses. You should also set the proper observer names (more than one is allowed). The IC selections are automatically set on startup and shouldn't be changed.

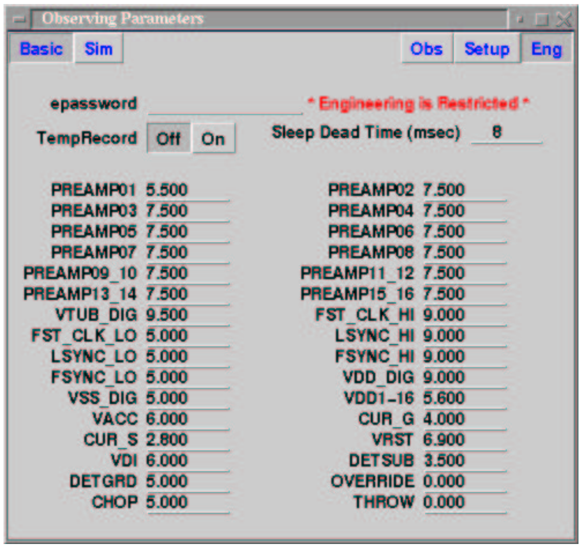


Figure 7: The "Eng" Window

You might now select the **Eng** window (Figure 7) to see a lovely display of all the system bias voltage values. These values are password protected, but should never need to be changed anyway.

Now reselect the **Obs** window, and click on the **Go** button back in the main XUI panel. After the appropriate amount of time, stunningly beautiful data[1] should appear in the VF panels.

[1]Your mileage may vary.

3 Procedure Checklists

The preceding section was a lot of information to blow past at one time and there are other things which need to be done to obtain the data, so let's work through a couple of examples at the IRTF, since that is where the greatest number of you will be using MIRLIN. Palomar and Keck will have similar procedures, just with different numbers.

3.1 Logging in

1. Check that the MIC program is running. On the PC monitor next to the Sun workstations, you should see a program running that says "MIRLIN – The Lean, Mean, Observing Machine!" at the top. If not, at the mirlinrack login prompt, login as "`camera`" with the password "`knock_knock`". It should then say "starting MIC in 5 seconds". Let it start and things should then be okay.

2. Log into your guest account.

3. If you like having the left mouse button pull down menus in MIRLIN's software as well as the right mouse button, edit your `~/.Xdefaults` file and change the `OpenWindows.SelectDisplaysMenu` entry to true. Issue the command "`xrdb .Xdefaults`" after doing this. (This only needs to be done immediately after you edit the file. Future logins will have this behavior automatically.)

4. Right click on the background, then select MIRLIN ▷ MIRLIN XUI. This will start the X User Interface.

5. Right click on the background again, perhaps on the second monitor, and select MIRLIN ▷ MIRLIN VF. This will start the MIRLIN-specific ViewFits program.

6. If MIC was already running, then in MXUI, select Parameters ▷ Init.

7. Select Parameters ▷ Change to get the Observing Parameters window where you will do most of the MIRLIN control.

3.2 Setting the chopping secondary controller and telescope nod

1. On the black Chopping Secondary Mirror Control box, set the Function to the square wave.

2. Use the coarse and fine throw knobs to set the chop throw. Note that the displayed throw is not very accurate: I'm using a setting of 24 to get a true 20 arcsec chop.

3. Change the meter knob to direction, then use the red direction button to set the chop angle. Again, the fidelity isn't very good: I have a setting of 14 degrees for a true N/S chop. Change the meter knob back to throw.

4. For the telescope nod, shout the direction and magnitude over to the telescope operator.

3.2.1 Chop/Nod in a square pattern

1. Change to the Observing Parameters "Setup" page.
2. Set the secondary mirror controller to a 20 arcsec throw, at a 0 degree position angle.
3. Set the telescope nod to 20 arcsec east.
4. Enter the values on the "Setup" page appropriately.
5. Check the deadtime values to ensure they are okay.
6. Flip back to the Observing Parameters "Obs" page.
7. Use this mode for bright, not-too-extended objects.

3.2.2 Chop/Nod in a "three beam" pattern

1. As above, but set the nod direction to be the same as the chop direction.
2. Tune the chop throw and perhaps the chop angle so that the two center beams coincide as precisely as possible.
3. Use this mode for faint objects when using a 64×128 subarray.

3.2.3 Chop/Nod in a diagonal "three beam" pattern

1. Warn the telescope operator that you are about to rotate the secondary—this will move the boresight and require reacquisition of the star! The operator can steer the telescope as you are rotating to avoid losing the star.
2. Follow the steps in section 3.2.1 above, but rotate the chop angle to 45° and the chop throw to perhaps 25–30 arcseconds.
3. Set the nod north and nod east to be the chop-throw/$\sqrt{2}$.
4. Tune the chop throw and perhaps the chop angle so that the two center beams coincide as precisely as possible.
5. Use this mode to search for very faint, extended objects.

3.3 Acquiring the first star

Let start with a moderately faint star, HR 5013, a 2.1 magnitude (5 Jy) star at 10 μm.

1. Select the N5 (12.5 μm) filter.
2. Set the **Obs Mode** to Chop - we're just trying to set our Itime and find it first.
3. Set the **Itime** to 30 msec (a guess).

4. Set **coadds** to 3 — chop freq indicator says 4.1 Hz. Good enough.
5. Press “GO” — sky value says 6800 — Itime is okay, leave it alone.
6. It’s a moderately faint star - let’s try 100 **chop** cycles.
7. Press “GO” — there it is, fairly bright.
8. Move the telescope to center the star where you want it.
9. Set **Obs Mode** to Chop/Nod.
10. Fill out **Object**, **Comment**, **Data Path**, etc. appropriately
11. Turn on **Autosave Data**.
12. Press “GO”. Enjoy your new data.

3.4 Acquiring subsequent objects

3.4.1 Very bright stars

Now let’s go to α Boo, a bright mid-infrared standard which is commonly used to figure out the pointing and the focus. There aren’t many things in the sky which are brighter than the background, so 99% of the time, the Itime setting is determined solely by the filter selection and the background contained therein (as in the first example); *i.e.* you can usually determine the Itime for a filter once at the beginning of the night and use it all night (unless the sky conditions change). However, α Boo is one of those things that is brighter than the background, so we need to twiddle Itime.

1. Set the **Obs Mode** back to Chop
2. Reduce **Chops** back down to a few to not waste a lot of time
3. “GO” — the background still has 6800 counts, but the peak of α Boo is about 11000.
4. Reduce **Itime** to 20 msec
5. Bump **Coadds** up to 4 to keep chop frequency roughly constant
6. “GO” — the background has now dropped to 4600 counts, and the peak is around 8000, which is okay.
7. As it is not a faint star, 30 chops should be plenty (you want at least 2–3 seconds of total integration time to blur out whatever seeing might be lurking about).
8. Go back to step 8 of the first star example.

3.4.2 Very faint stars

Now a faint source (for the IRTF, at least). HD 161903 is a near-infrared "Elias" standard of about 7th magnitude (~ 55 mJy at N). We want to use broadband N for maximum sensitivity, but we can't read out the full array at the IRTF fast enough, so we set subarray mode.

1. Set the **Obs Mode** back to Chop
2. Reduce **Chops** back down to 1
3. Click on the **Array** icon. Select 64x128.
4. Click on the **Filter** icon, select N
5. Set **Itime** to 4.2 msec
6. Set **Coadds** to 20 — chop freq will be about 5.5 Hz.
7. Check your background with a quick GO. If okay, then procede.
8. Since it is faint, 500 **chops** is reasonable
9. Set the number of **cycles** to 10 perhaps. Maybe more.
10. Click GO. As the cycles progress, they will be coadded to the accumulator and you should see the star rising out of the ashes. You can press the Stop button before the number of cycles is complete if you decide you have enough S/N. All the data has already been written to disk, so you lose nothing stopping in the middle. If you are clever, you will push the Stop button during the second half of the nod; failure to do so may leave the telescope in the off-beam position. Check your coordinates before continuing.

3.5 Focusing

1. Find a bright star (N < 0), e.g. α Boo, β Peg, etc.
2. Set **Obs Mode** to Chop.
3. Choose the N5 (12.5 μm) filter
4. Set **Itime**$\times$ **Coadds**$\times$**Chops** to 2–3 seconds
5. Set **Cycles** to something large, like 100. Push GO.
6. On the upper right panel of VF, monitor the shape of the star.
7. At best focus, you should see at least a hint of a diffraction ring. Aim for a compact core with a distinct ring; out-of-focus images will display some astigmatism which can be used as a guide to best focus.

3.6 Autoguiding

Getting the chopping and nodding to line up exactly is critical if you want to do the traditional “3-beam” chopping.

1. Set the coarse chop and nod throws as described above.
2. Take a few images in Chop/Nod mode to see how the two central peaks stack up.
3. Adjust the chop throw and angle until the two center peaks are coincident most of the time. Don’t be afraid to tinker quite a bit - the guider has fewer troubles if you do a good job here.
4. Have the operator find a guide star and turn on the guider.
5. The central peaks should now *always* be coincident.

4 Deeper Into the Details

4.1 Powering Up MIRLIN

If you need to power up MIRLIN (this should be done already, however), first turn on the computers. The Sun Sparcstation should always come up just fine. In principal, the rackmount PC should too, but experience has shown that 50% of the time you must plug in the keyboard in order for it to boot successfully. Unplug the keyboard after it starts to boot (the red disk activity LED should get very busy while it's booting). *Never, ever* (**!**) turn off either computer without first shutting down the operating systems. The simple (and desired) solution is never turn them off, but if you must, see the section on shutting down MIRLIN.

After this, turn on the Lakeshore temperature controller and the black stepper motor driver box (any order). I sometimes have trouble establishing communications with the motor controller—it can require many on/off cycles to get it cooperating; however, once it is operating, I have no further trouble. Finally turn on the array electronics power supply box. Once the system is fully operational, nothing should be turned off until the end of the run—do not turn things off at the end of the night.

4.2 Starting the Software

The startup sequence for the software is not difficult, but it is not yet particularly friendly. First log onto the Sun Sparcstation as user `camera` and enter the appropriate password. This should log you in and automatically start X Windows. A few xterms will be started for you. The only one we really care about is the one for running the instrument control (IC) program. Choose the lower left screen (usually green), then type `rack` at the prompt. This should log you into the rackmount PC which is mounted on the telescope. You may need to supply the password. Then change directory (`cd`) to `ic`, and type `mic` at the prompt. This should start up the IC program. You should wait until things have initialized and the time counter has appeared in the upper right corner of the xterm. The xterm should look something like Figure 8 before proceeding:

Now select the upper left xterm (yellow) and simply type "go". This will start the X user interface (XUI, Figure 1) and the "View FITS" program (VF). You should now be ready to begin taking and displaying data. If a number of socket error messages or math error messages appear in the xterm, you didn't wait long enough for the IC to initialize. Kill XUI and VF and type "go" again.

4.3 Taking Data — The Long Version

This section does not cover every detail of the instrument operation or of the software parameters. Some knowledge of infrared astronomy and computer literacy are assumed. We will, however, discuss some considerations in a detailed way in order that useful data may be obtained; these are things which apply specifically to MIRLIN (and not other infrared cameras) or which we consider to be not obvious (*i.e.* we learned it the hard way).

4.3.1 Observing Mode

The observing mode allows you to choose what sort of background frames, if any, are obtained in the observing sequence. First a few quick definitions: 1) Staring is simply looking at the sky, no motion

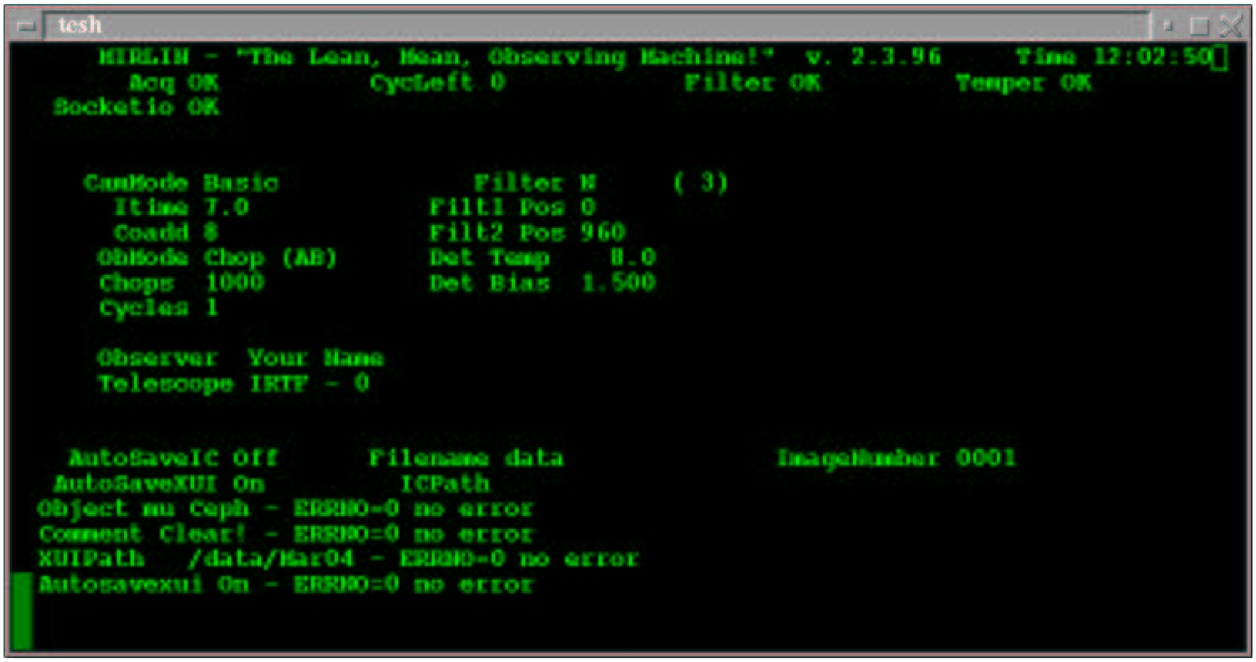
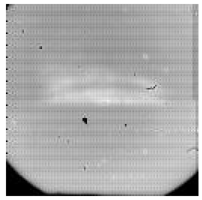
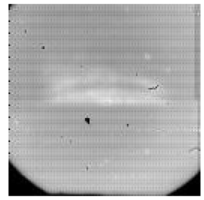


Figure 8: The IC XTerm

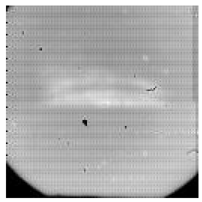
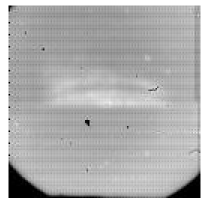
whatsoever. There are two MIRLIN modes which stare: OBJ and SKY. The only difference is to which VF buffer they are written. The only reason to write them to different buffers is so that you can control what is positive and what is negative in an object minus sky subtraction. 2) Nodding is moving the entire telescope between two locations on the sky, typically one with the object in the field-of-view (hence OBJ) and one with it out of the FOV (hence SKY). It can take from 3 to 10 seconds to allow the telescope to settle during moves, thus nodding is generally done only at near-infrared wavelengths (thus generally never with MIRLIN, except perhaps with the CVF), or as part of a more complicated procedure (see below). 3) Chopping is toggling the telescope secondary mirror between two limits to move the object in and out of the field of view. This is much faster than nodding; it takes approximately 2 to 5 milliseconds to settle, thus one can chop between the two positions at over 40 Hz given a 5 msec integration length plus overhead. 4) Chop/Nod mode allows a combination of chopping and nodding. In this mode, a full chopping sequence is performed and the difference is displayed, then the telescope is nodded to its new position and another chopping sequence is done. The difference between these two chop beams is subtracted from the first difference to give the final image.

The chop/nod sequence is important because chopping effectively changes the optical "shape" of the telescope. Small differences in the illumination pattern (*e.g.* dust on the dewar window) will cause artifacts in the residual which can be quite large in comparison to the object. The second chop sequence in the pattern should have the same residual error as the first, thus subtracting it should remove the residual. Perhaps Figure 9 will make things clearer.

In this example, both the chop throw and the nod shifts are small so that the object is always on the chip. Sometimes, particularly with extended objects, one must chop and nod into completely blank sky; thus the object is in the field of view only 25% of the time. A reasonable alternative to chop/nod is taking one chop sequence entirely on blank sky, then taking many chop sequences (perhaps moving the telescope slightly between each) on the object, then another blank sky sequence. Since the residual

A.  C. 

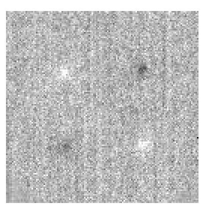
The positive chop position for the two nod positions, respectively.

B.  D. 

The negative chop position for the two nod positions, respectively.

A-B.  C-D. 

The differences of the chop sequences. The left image is displayed at the end of the first chop sequence; the telescope is then moved and the right image is seen after the new chop sequence.

(A-B)-(C-D). 

The final image. The second chop sequence is subtracted from the first to remove the residual slope and waves.

Figure 9: The Chop/Nod sequence of images.

slopes and waves vary very slowly with time, it is probably not necessary to do the blank sky residual more than once or twice per object. These sky frames can then be subtracted from all the on-object sequences to eliminate the residuals. Care must be taken, however, so that the noise in the sky frames is sufficiently small that it does not impact the detection limit.

4.3.2 Itime

The “Itime” parameter sets the single, on-chip integration time. This time will almost always be set by the thermal background of the sky and telescope as opposed to the brightness of the object. The key to selecting a proper itime is to understand the competing characteristics which affect the data. The first issue is linearity. Lab tests show that the detector is linear to 1% from 0 to 9,000,000 electrons (7000 ADU swing, about 8000 ADU final signal level). This will normally set the upper limit of itime unless you are prepared to deal with linearity correction issues. The lower limit is set by the read noise. Zero signal presents itself as about 1,000 ADU. Since the total system noise (read noise plus electronics) is about 1400 electrons, your signal should be at least 2000 ADU (final level > 3,000).

4.3.3 Coadds vs. Chops

Since both the number of coadds and number of chops are essentially free parameters, this is how I suggest setting them. Use the number of coadds to set the chop frequency you desire. For example, if you are doing 10 msec integration and decide that a 5 Hz chop frequency is the most desirable, then you will find that about 8 coadds will yield this frequency. (Use the Chop Freq line to monitor how the number of coadds affects the frequency.) Then set the number of chops (chop cycles) to give the signal-to-noise you desire. If in the current example you decide that you need twice the S/N, then increase the number of chops by a factor of 4, while leaving itime and coadds alone.

4.3.4 Bias Voltage

The detector response varies *roughly* as the square root of the detector bias for voltages between about 0.5 and 2.0 V (thus S/N$\propto V_{bias}^{0.25}$). The optimal setting is about 0.75 V; voltages higher than this lead to excess read noise and bleeding around bad pixels. If you are having saturation problems with broadband N, don't adjust the bias—use a half-frame readout mode instead.

4.3.5 Filters

The following table indicates the available filters and their bandwidths. There is room for only 13 filters at a given time, and we have settled on a standard selection. Specific filter replacement requests will be considered, but they must be extremely well justified and made well in advance of the observing run.

Table 1: Filter Lists

Name	λ (μm)	$\Delta\lambda$ (μm)	Flux (Jy 0 Mag)
K	2.2	0 .4	650
M	4.68	0.57	165
N	10.79	5.66	33.4
Q-s	17.90	2.00	12.4
Q-l	22.43	4.85	7.9

Name	λ	$\Delta\lambda$	Flux	Name	λ	$\Delta\lambda$	Flux
N0	7.91	0.76	60.9	Q0	17.20	0.60	13.4
N1	8.81	0.87	49.4	Q1	17.93	0.45	12.3
N2	9.69	0.93	41.1	Q2	18.64	0.52	11.4
N3	10.27	1.01	36.7	Q3	20.81	1.65	9.2
N4	11.70	1.11	28.5	Q4	22.81	1.21	7.7
N5	12.49	1.16	25.1	Q5	24.48	0.76	6.7

Figure 10 shows these filters in relation to the atmospheric transmission (for Mauna Kea). There is also a 2% spectral resolution circular variable filter (CVF) which has a useful wavelength range of approximately 7.5 to 13.7 microns.

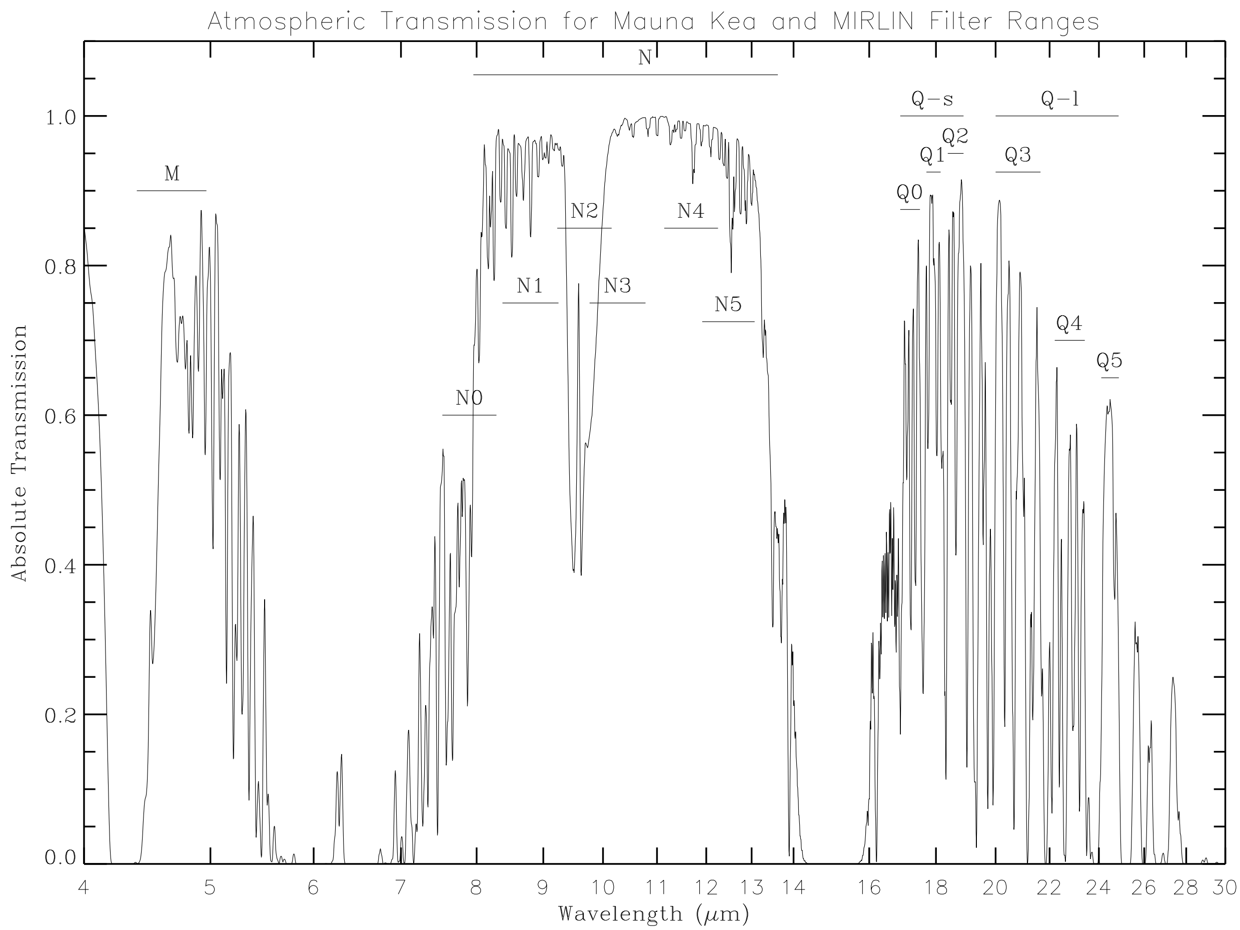


Figure 10: Atmospheric transmission for Mauna Kea and MIRLIN's filter passbands.

4.3.6 Is it a 20 μm night?

The atmosphere in the mid-infrared is maddening - at 11 μm, the it is almost completely transparent, while at wavelengths > 17 μm, it's like extremely variable soup. The CSO has given Mauna Kea an extremely valuable tool with their 225 GHz optical depth monitor. A quick look at their Tau Now (Brown Cow) entry (at `http://puuoo.submm.caltech.edu/`) allows one to immediately gauge whether its worth attempting 20 μm observations or not. The rule of thumb as I have found it is as follows (tongue firmly in cheek):

- $\tau > 0.4$: go home
- $0.2 < \tau < 0.4$: 10 μm window only
- $0.14 < \tau < 0.2$: 18 μm if you are desperate
- $0.07 < \tau < 0.14$: good for 18 μm, 20-25 μm okay for brighter sources
- $0.04 < \tau < 0.07$: excellent for all wavelengths
- $\tau < 0.04$: park the filter wheel at 24.5 μm, tie the telescope operator to his chair, crank up the stereo, and attempt to image every known object in the sky!

4.3.7 Flat Fields

We have not yet determined the best way to apply traditional flat-fields to MIRLIN data. We have had some success with using dome minus sky images as well as high airmass minus low airmass images. Unfortunately, there appears to be some variation in flatness over the array due to the optics. We are actively working on this, but in the mean time, to cover yourself as well as possible, try to keep your objects and standard stars in the same position on the array—the pixel-to-pixel variations are much smaller than the global, optics-induced variations.

4.3.8 Dewar Rotation Angle

Because MIRLIN was designed to be used at both Palomar in a side-looking configuration and at the IRTF in an up-looking configuration, compromises had to be made in order not to dump all the cryogens at one telescope or the other. This led to the placement of the fill tubes near the window "edge" of the dewar top. We have since found the the fill tubes may not be placed exactly horizontally or pointed downward; this leads to an order of magnitude higher liquid helium boiloff rate. Consequently, the dewar must be rotated depending on what part of the sky is being observed. At the IRTF the cutoff is simple, any object which is south of zenith ($\sim 20^\circ$) requires that MIRLIN's fill tubes be pointed north (0° rotation angle); north of zenith requires that they point south (180° rotation angle). Be warned that anything within two degrees of zenith (18–22°) may cause increased boiloff.

At Palomar, when the dewar is on the north side (90° position angle), declinations from +15 to +90° may be observed. When it is on the south side (270° position angle), declinations from -35 to +50 may be reached. The overlap is due to the 20° tilt at which MIRLIN is mounted on the infrared coffin.

In the software on the "Change Parameters" page, the telescope icon will allow you to pick the dewar orientation. The software will then generate the commands necessary to rotate and flip the images so that north is always up and east is always left on the display. The direction of pixel 0,0 is also printed in the FITS header.

4.3.9 VF Tips and Tricks

To center up on your object, the most convenient trick is to call up the **TCS Coordinates** box under **Options** in VF. Simply click on the current position of the star, then press "f" (for "from"). The pixel coordinates should appear in the panel. Then click on where you would like the star to be and press "t" (for "to"). Then press **Calculate Offset** followed by **Offset TCS**. The telescope should move the distance indicated by the calculation. The next image you take should have the object exactly where you did the "to" click.

To aid in focusing, it is useful to display line cuts through a star. To do this, obtain an image of a star; this should be displayed in Panel C (upper right) which by default displays Buffer 2 assuming you did a normal chop. Now click on Panel D. Where it indicated that it is displaying Buffer 3, change this by selecting Buffer 2 (b2). Where you probably see **Image**, change this by selecting **Line cut**. A line cut plot should now appear in the lower right panel. Click on the star in Panel C, then press "l" ("el") to have the cuts go through the point you clicked. You can restrict the plot range by drawing a box around the star in Panel C with the middle mouse button, then selecting **Box** on the Panel D setup.

4.3.10 Saving data with the CD-ROM writer

MIRLIN has a CD writer for backing up data at Palomar; CD's have greater longevity than tapes and they can also be used directly by data processing software. Writing CD's is not difficult; a simple shell script is all it takes. To write the CD, follow these steps:

1. Put a new CD into the CD caddy and insert it into the writer.
2. Type "make_cd /data". Everything in the /data directory will be written to the CD. You can specify subdirectories of /data if you wish.
3. Come back in an hour and pick up your nice, shiny CD.

If you want to make a second copy, type the command "burn_cd" to make the second. This command assumes that a disk image already exists as /cdimage/image (which is created as part of the "make_cd" command).

4.4 Shutting down MIRLIN

If you are only shutting the system down for the night, all you need to do is select the "dark" filter, then press the **Halt** button under "Parameters" in the XUI or issue a **halt** command from either the XUI or the IC. When the "GO" status reads "Halted", then exit from all the software (**Quit** buttons in VF and XUI, you can leave MIC running). Do *not* turn off any of the electronics.

To shut the entire system down at the end of a run, first exit the software as described above. Logout from the rackmount computer, then issue the command **haltrack** from the Sun. This will shut down the rackmount. Now exit from X Windows and logout. Relogin as **halt**. This will shutdown the Sun workstation. After a few minutes you may turn off all the power in reverse order from the startup (i.e. first the array electronics power supply, then the motor controller, the temperature controller, the rackmount computer, and finally the Sun).

4.5 Error Recovery

In spite of my goal to have a perfect instrument, there are probably still a few little "nasties" running around the system. Most have been fixed, so that MIRLIN is now rather stable. However, if you should encounter a crash, here are a couple of things to try.

4.5.1 Recovering from a Software Crash

Should you experience a software crash, the simplest way to recover is to restart the software, then go to **Execute 'DO' Files** under the **Options** button in XUI. Assuming you are in the default macro directory ($HOME/macros), a file called "%%recall" should appear at the top of the list. This file was created automatically the last time you pressed the "GO" button, thus it should have the most recent system state stored in it. Simply highlight the file, then press "Execute" to reload everything. You should double-check the "Next Image Number" parameter to make certain you don't try to overwrite any existing files which may have been saved after you last pressed the "GO" button.

4.5.2 Clearing a GoTask ERROR state

If a non-fatal error when doing a Go occurs, press Stop to clear the ERROR state and return the GoTask state to READY. How do you know if it was a non-fatal error? Try this and if the next integration works, it was non-fatal.

5 Palomar and Keck Specific Information

We've covered the IRTF specific procedures in Section 3. Here we present details for Palomar and Keck.

5.1 Palomar issues

5.1.1 Acquiring Objects

Finding mid-infrared sources can be tricky if they are not also optically visible, but the following routine seems to work relatively well. Figure 11 shows a "cartoon" of what you will see in the visible wavelength finder camera. The large square occulting the field of view is MIRLIN's pickoff mirror. First find a bright mid-infrared standard standard star and move it to the center of the top "crescent" to position A. Now move the telescope approximately 35 arcseconds north (perhaps south if the dewar has been rotated 180°) and center the star in MIRLIN's field-of-view (if it were not blocked by the pickoff mirror, this would be position B). Move the telescope south exactly 35 arcseconds (perhaps 30 or 40 arcseconds instead) and mark the new position of the star with the cross hairs. You might also wish to have the telescope operator perform an "X" at this point. I find it useful to have the operator define an "A" as the 35 arcsecond north (or whatever) move; when you center the object on the visible camera cross hairs, then ask to do a "move A", the object will then be well centered in MIRLIN. This way you do not have to remember which orientation the dewar is in or what exactly your offset is. Do a "move -A" to get the object back on the cross hairs.

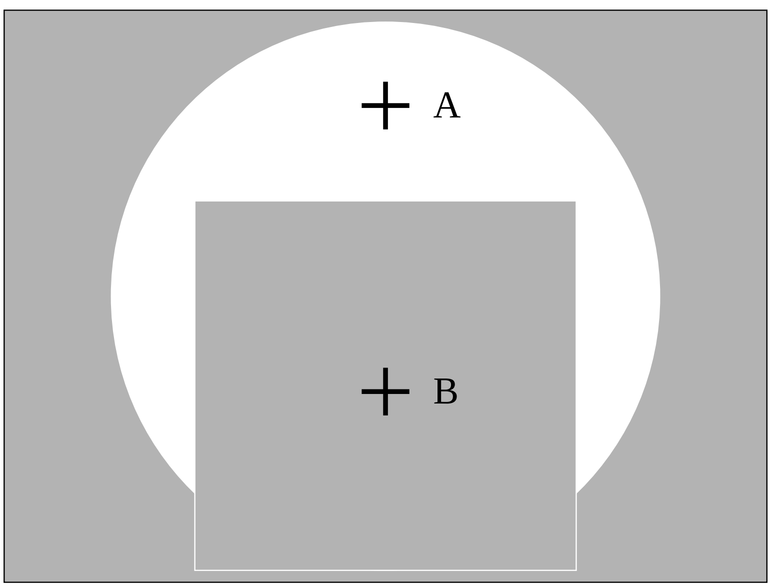


Figure 11: The finder camera field of view

If your object is optically visible, find the object in the visible camera and center it on the cross hairs, do a "move A", and take data. If the object is not visible, ask the operator to find a nearby SAO star, center this on the cross hairs, move to your object's coordinates, do a "move A", and take data. This sounds like a lot of moving, but our experience is that the 200″ seems to point extremely well, and assuming the object's coordinates are good, it will fall within an arcsecond of your target spot. See section 4.3.9 for tricks on how to center up on the object.

5.1.2 Setting the Chopper Throw and Angle

The f/70 chopping secondary mirror is controlled by signals generated by MIRLIN's electronics in order to synchronize the position of the mirror with the data frames. The throw signal is currently converted to f/70 language by a small gray box which is located in the data room. To set the throw, find the "Chop Throw" item on the Setup page under Observing Parameters in the XUI. The valid range is from 0 to 133 arcsec.

The chopping angle is controlled directly by the chopper electronics. On the front panel is a red LED display labeled "ROTATION" with a toggle switch underneath. Press this toggle switch until the desired angle (east of north) is displayed in the readout.

5.1.3 Guiding

Here is a quick recipe for finding guide stars with the offset guider. At the beginning of the night, do the following:

1. Find a bright standard and center it in MIRLIN's field of view.
2. Zero the telescope offsets. This can be done by typing "tcs z" in the command prompt area of MXUI or asking the telescope operator to do it.
3. Put the guider position at its origin (type "og r 0 0" at the guider computer prompt. It may take a while ($\sim$ 30 seconds) to complete the move.
4. Move the telescope until the star is centered in the guider field of view (about $10''$ across).
5. Record the offsets from the telescope coordinate display. North and east are positive. For example, if the offsets are 10 arcsec west and 20 arcsec north, record this as "-10 20".
6. Move the guider out of the center position (*e.g.* "og r 60 0")

Then for each object, perform the following:

1. Position the object in MIRLIN's field of view in the normal way (SAO star, move to object, move A, etc.)
2. Enter the guide star offsets into the computer, e.g. "og r 35.6 -92.3" for a 35.6 east, 92.3 south offset.
3. Offset an additional distance corresponding to the offsets found above, e.g. "og i -10 20".
4. The guide star should be in the guider field of view. Do additional "og i" moves to center the star as necessary.
5. Move the guider cross hairs into the guider "hex", but not on the star, by pushing the blue buttons on the guider box.

6. Twiddle the “H-ZERO” and “V-ZERO” knobs on the guider box until the red lights flash in a balanced manner.

7. Read the HEAD angle from the guider computer and dial that number into the thumb wheels on the guider box. Check that the mode knob is set to mode 11.

8. Move the cursor onto the star and turn on the guide switch. The LEDs should flash green when the guider starts “pushing” the star to the center of the cross hairs.

5.1.4 Twist-and-Shout

To “twist and shout” (align the instrument optical axis with the telescope optical axis), it is necessary to adjust the gold pick-off mirror which is inserted into the Infrared Coffin. There are two micrometers, one which controls up-and-down (north-south) movement of the pick-off mirror, the other controls side-to-side (east-west). The overall goal is to have the dewar look precisely at the secondary mirror so that a uniform, low background is seen across the whole MIRLIN field-of-view. The background signal increases dramatically when the pick-off mirror is misaligned, so the twist-and-shout attempts to minimize this. The twist-and-shout works best with two people: one to adjust the micrometers, one to take images and call out movements to optimize the position. The twist on shout can generally be done in the afternoon or early evening. Simply have the telescope pointed at zenith and make sure both the primary mirror cover and the secondary mirror lid are open. As long as the background is not greatly varying, this should be sufficient. The alignment can also be tested by observing a very out-of-focus star: the image should be round and symmetrical.

5.2 Keck Issues

Observing at Keck with MIRLIN yields tremendous results. But part of the price for those results is that more effort is required to perform the observations. This section describes things that must be done differently from or in addition to the procedures mentioned in the main body of the User Guide. This section assumes that you are logged onto makapuu, the SunOS 4 machine in the Keck II remote operations room in Waimea.

5.2.1 Software startup

Log onto makapuu as user “mirlin”. On the screen labeled makapuu:0.1 or makapuu:0.2, pull down a root menu with the right mouse button. You should see an entry “MIRLIN” at the top; from the submenu under that, select Start TCS, then Start IC. If you want to the summit to see a mirror of the MIRLIN control software, go to Section 5.2.2, otherwise, select Start XUI and Start VF. These two programs should appear automatically on the makapuu:0.0 screen.

At this point all the MIRLIN software is running, but there are a few other useful Keck supplied utilities you should probably start up. The most useful is a compass rose indicating the direction of north in the MIRLIN images. In the root pulldown menu, find “Instrument Directions”. This will start a small panel labeled “tkrose (i)”. Make certain it does not say “tkrose (g)”; that is a guider rose which has nothing (directly) to do with the MIRLIN orientation.

Other useful programs are “K2 Telescope Status->Facilities Summary” and “Chopper focal plane display”

5.2.2 Mirroring the software on the summit

To "mirror" the MIRLIN control software to people on the summit who are logged onto kua as "mirlin", perform the following exactly—do not deviate from it at all! Start TCS and IC in the normal way mentioned above. Then:

On makapuu:

- Find an available xterm, then type "`xmx :2 -p -display makapuu kua`". You will see many error messages about color allocation. This is normal behavior; any other error messages, however, are a cause for concern.

On kua:

- At any prompt, type "`setenv DISPLAY makapuu:2`". Note: this is NOT makapuu:0.2!
- At the prompt, type "`xterm`". This will start an xterm which should be visible on both makapuu and kua.

On makapuu in the new xterm:

- `rlogin -l camera mirlinkeck` (passwd: knock_knock if needed)
- `start_keck`

Everything should now be running, and you can begin to set the observing parameters. If for some reason the "start_keck" script doesn't behave as advertised, here is what it does:

- `setenv DISPLAY makapuu:2` (NOT makapuu:0.2!)
- `xv &` (this is to steal colors, so that mvf and mxui are forced to use their own colormaps)
- `cd vf`
- `mvf &`
- `cd ../mirlin/xui`
- `mxui &`

You may now kill xv, as it was only needed to force the colormap sharing.

5.2.3 Point and click pointing issues

The "point and click" functions in the VF program (Options->TCS Coordinates) behave as at the other telescopes. The variation is that VF cannot rotate the image to be north up and east left given the arbitrary rotator angles at Keck. To still allow good point and click control, set the Angle to the PA shown in the tkrose (i), e.g. if the tkrose says "PA -82.65", then type in -82.65 for the Angle entry (actually, rounding off to the nearest degree will be adequate). Make sure the platescale is set to 0.138. The point and click will then work as expected.

5.2.4 Sending chopper commands

MIRLIN does not yet directly control the f/40 chopper; there are good reasons to never have it do so. To set various chopper parameters, type the following commands at the “Command:” prompt in the top XUI panel (for example):

- `tcs chopamp 10.0` (sets chopper throw to 10 arcsec)
- `tcs chopang 90` (sets chopper direction to 90 degree east of north)
- `tcs chopfreq 5` (sets maximum chopper frequency to 5 Hz, see below for more discussion)
- `tcs chopon` (this sends the data mentioned in the previous three commands)
- `tcs chopoff` (shuts down the chopper)

You must enter a chopon command after any of the other commands for it to take effect. You may issue one or several chopper commands before the chopon command; you don’t have to issue it after every command.

5.2.5 Chopping frequency problems

The f/40 chopping secondary employs an active error correction driver to boost its performance. The problem with this is that the chopper needs to know what frequency to expect the chop signals at. Since MIRLIN’s chop frequency is determined by the itime, number of coadds, and the chop deadtime you have selected, changing any of those parameters changes the frequency, and in principal, that chop parameter should be changed. However, any time you change any of the chopper parameters, the next integration is screwed up. Thus, to minimize wasted data, we typically set the expected chop frequency to 5.0 Hz, then tickle itime, coadds, and chopdtime to always remain a little below this (e.g. aim for 4.0 to 4.8 Hz in the XUI Chop Freq field). As long as you aim for this window, you never have to change the expected f/40 chop frequency.

5.2.6 Dewar rotation angle

Because MIRLIN was designed to be a compromise between an uplooking and a sidelooking dewar, it is the worst possible configuration for Keck, which essentially wants downlooking dewars. As a result it is all too easy to accidentally dump all of the cryogens by moving the instrument rotator to a bad angle. Depending on the telescope elevation, there is a range of about 130–180 degrees in which the dewar can be rotated safely. There is a chart which the OA should have which shows the optimum rotator angle, and the safe range of deviation from this angle. Any guide stars you may want to use must fall within these angle limits.

For reference, the rotator “drive angle” for the dewar fill position is $+40^\circ$; straight up is -10°; the stow position, which is “safe” for any telescope elevation, is -50 to -60°.

A Command Summary

A.1 Commands common to both IC and XUI

This section summarizes all the commands such as they would appear in a macro file and lists them in the following form:

function name `default value` [value range] description.

I have tried to be careful to indicate floating point values with a decimal point and at least a tenths digit, while integers do not have a decimal point (*e.g.* "10.0" vs. "10"). Things which don't have a sensible default value or range are indicated with a "—" in the appropriate entry.

accumulate	`off`	[on/off]	Accumulate the difference frames gathered during nodded observations into VF buffer 3.
array	`full`	[full/half]	Select full frame or half frame (64×128) readout mode.
autosaveic	`off`	[on/off]	Automatically save the data on the IC host computer (not implemented)
autosavexui	`off`	[on/off]	Automatically save the data on the XUI host computer.
beameast	`0.0`	[$-300.0 \rightarrow 300.0''$]	Set the east nodding distance (Palomar only).
beamnorth	`0.0`	[$-300.0 \rightarrow 300.0''$]	Set the north nodding distance (Palomar only).
cammode	`basic`	[basic/sim]	Set the camera mode.
chopdtime	`10`	[1 → 500 msec]	Set delay between chop transition and start of integration in msec.
chops	`1`	[1 → 32768/coadds]	Set the number of desired chop cycles. (Coadds × chops must be < 32768.)
chopthrow	`0`	[$0 \rightarrow 133.2''$]	Set the chopping secondary mirror throw.
coadd	`1`	[1 → 32768/chops]	Set the number of coadds per beam/chop.
color	`no`	[yes/no]	Set color attributes for IC terminal.
comment	`no`	[—]	Set the comment for the FITS data file.
cvf	—	[7.5 → 13.7 microns]	Set the filter wheels to this CVF wavelength.
cycles	`1`	[1 → 1024]	Set the number of telescope nod cycles.
destripe	`off`	[on/off]	Automatically destripe the subtracted image data.
display	`?`	[0 → 2]	Determines how the kbio process updates the parms window on the screen.
dtime	`1.0`	[0.0 → 30.0 sec]	Set the telescope settling time after a nod move.
epassword	—	[—]	Enter the engineering password.
filename	`data`	[—]	Set the filename prefix to be saved.
filter	`open`	[filter name]	Select the filter (open, dark, N0, N1, etc.)
filterinit	—	[—]	Initialize the filter wheels.

go	—	[—]	Begin an integration.
goinit	—	[—]	Initialize the electronics.
goreset	—	[—]	Reset the electronics.
halt	—	[—]	Halt the electronics.
imagenumber	`1`	[1 → 9999]	Set the next image number.
itime	10.0	[5.0 → 60000.0 msec]	Set the integration length.
nop	—	[—]	Do nothing (useful for some internal initialization routines).
object	`Object Name`	[—]	Set the object name.
observer	`Your Name`	[—]	Set the observers' names.
obsmode	3	[0 → 5]	Pick the observation mode; 0 = stare(A), 1 = stare(B), 2 = nod, 3 = chop, 4~=~chop/nod, 5 = movie (not implemented).
setbias	—	[0.0 → 10.0 V]	Set a bias voltage; has the form setbias board,dac,voltage; will disappear in the near future.
setrbias	—	[0.0 → 10.0 V]	Set a bias voltage; has the form setrbias board,dac,voltage; requires the engineering password.
sleepdtime	`50`	[1 → 1000 msec]	Amount of time to wait before checking if integration is done. Don't change this unless you are sure you know what you're doing.
status	—	[—]	Doesn't appear to do anything.
stop	—	[—]	Stop an integration. Breaks only at nod or chop changes, so mistakes when doing a long stare or nod only can get long and boring.
subab	`off`	[on/off]	Automatically subtract A and B beams in VF buffer 2 when chopping or nodding.
tcs	—	[—]	Send a TCS command.
tcshostname	`mirlin`	[—]	Set the TCS host computer name.
telescope	`0`	[0 → 6]	Sets the telescope identifier (0 = Palomar at 90 deg, 1 = Palomar at 270 deg, 2 = IRTF at 0 deg, 3 = IRTF at 180 deg, 4 = Keck at 0 deg, 5 = Keck at 180 deg, 6 = Other).
tempcmd	—	[—]	Send a temperature controller command.
temprecord	`off`	[on/off]	Record the temperature to a file; requires the engineering password.
wait	—	[0.005 → 60 sec]	Set GO busy for n seconds.
xuihostname	`mirlin`	[—]	Set the XUI host computer name.
xuipath	`/data`	[—]	The the path for XUI macros.

A.2 Commands in IC only

die	—	[—]	Quit the IC program.

A.3 Commands in XUI only

dofile	—	[—]	Execute a macro file
dofilemask	`*`	[—]	Set the mask for displaying available macro files.
dopath	`$HOME/macros`	[—]	Set the path to find macro files.
ichostname	`mirlinrack`	[—]	Set the IC computer host name.
pwindow	`0`	[0 – 2]	Select the parameter window; 0 = observing, 1 = setup, 2 = engineering.
vf	—	[—]	Send a VF command.
zeroaccumulate	`off`	[off/on]	Clear accumulator panel (momentary on).

B Topping off the cryogens at Palomar

Most of you should never have to deal with topping off the cryogens in MIRLIN, but if you should find yourself in that position, here is the instruction list. For your information, the LHe hold time is roughly 32 hours, the LN_2 hold time is significantly longer than that, and it is best to do the transfer after the night's observing, rather than before, to minimize cryogen spillage.

- Two shorting plugs
- 3/16 ball driver
- Window cover plus #2 screw
- Small slotted screwdriver or 5/64 ball driver for #2 screw
- Metal block (for supporting LHe transfer tube above dewar)
- LHe transfer tube
- Funnel, LN_2 flasks

Procedure:

1. If necessary, follow the instructions for shutting down the MIRLIN software. If the "Gotask" status in the XUI panel on the Sun workstation reads "Halted" (purple letters) or if the XUI and IC programs have been shut down (command prompts visible in the probably green and yellow xterms), it is safe to proceed.
2. Turn off the array electrnics power supply, the filter motor controller, and the temperature controller (if present) in that order.
3. Remove the gray housekeeping and motor drive cables from the dewar.
4. Place one hand on the electronics box, then remove the array cables from the dewar with your other hand. Immediately insert the shorting plugs after removing the cables. (If you don't have the plugs, don't remove the cables!)
5. Place the window cover back over the dewar window.
6. Remove the screws which clamp the dewar into the instrument mount.
7. Slide the dewar out of the mount and gently place it on the floor. Warning: the dewar weighs approximately 90 lbs. empty.
8. Remove the rubber boiloff control tubes. The nitrogen tube has a simple screw-on cap, the helium tube has a safety "widget" with a stopper that functions as a pressure relief.
9. Position the LHe dewar near MIRLIN by putting the dewar on the "mushroom" (ram/platform/whatever-you-call-it) and raising it so the neck is at the Cass cage floor level inside the access door.
10. Retrieve the LHe transfer tube and slide the o-ring to near the bottom.
11. Close the 1/2-lb safety valve on the LHe dewar and slowly insert the transfer tube into the neck. Tighten the o-ring nut as soon as possible to get a leak-proof seal.
12. Watch the pressure gauge on the LHe dewar. You would like the pressure to rise to roughly 7–8 lbs. If it goes over 10, open the safety valve to drop the pressure a bit.
13. Continue pushing the tube into the dewar. Ultimately, the tube should be 1/4 inch from the bottom (push it down to the bottom, then pull back a bit).

14. When a strong solid white jet appears at the transfer tube tip (looks something like a blowtorch), insert the tip into MIRLIN's LHe can. You should see a milky white plume approximately 6–12 inches tall (depending on humidity conditions) while the liquid is transferring.
15. After some time, the plume will begin to billow and spit little streamers of condensate. This indicates the can is full. (8 liters total capacity)
16. Open the 1/2-lb or the large through-valve on the LHe dewar to vent the pressure, pull the tip from the MIRLIN LHe can, unscrew the o-ring nut, and remove the transfer tube from the storage dewar.
17. Close the LHe dewar neck and the large through valve. Open the 1/2-lb safety valve.
18. Reinsert the LHe boiloff tube.
19. Using a funnel and flasks of LN_2, fill LN_2 can until it overflows. (4.5 liters total capacity)
20. Reinstall the LN_2 boiloff tube.
21. Follow steps 2 – 7 in reverse order to put MIRLIN back on the telescope.
22. Follow the instructions for starting the MIRLIN software. (The day crew may omit this step, leaving it to the observers.)